US009094843B1

(12) **United States Patent**
Petrovic et al.

(10) **Patent No.: US 9,094,843 B1**
(45) **Date of Patent: *Jul. 28, 2015**

(54) **METHOD AND APPARATUS FOR ADJUSTING A GAIN OF A RECEIVER IN A WIRELESS DEVICE**

(71) Applicant: **Marvell International LTD.**, Hamilton (BM)

(72) Inventors: **Vladan Petrovic**, San Jose, CA (US); **Manyuan Shen**, Milpitas, CA (US); **Qing Zhao**, Milpitas, CA (US); **Leilie Song**, Sunnyvale, CA (US)

(73) Assignee: **Marvell International LTD.**, Hamilton (BM)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/319,133**

(22) Filed: **Jun. 30, 2014**

Related U.S. Application Data

(63) Continuation of application No. 13/101,628, filed on May 5, 2011, now Pat. No. 8,773,966.

(60) Provisional application No. 61/332,601, filed on May 7, 2010.

(51) **Int. Cl.**

H04L 1/00	(2006.01)
H04L 12/26	(2006.01)
H04W 24/00	(2009.01)
H04B 17/00	(2015.01)
H04W 52/52	(2009.01)
H04W 52/38	(2009.01)

(52) **U.S. Cl.**
CPC ***H04W 24/00*** (2013.01); ***H04B 17/0062*** (2013.01); *H04W 52/38* (2013.01); *H04W 52/52* (2013.01)

(58) **Field of Classification Search**
CPC H04W 52/00; H04W 52/04; H04W 52/52
USPC 370/252
See application file for complete search history.

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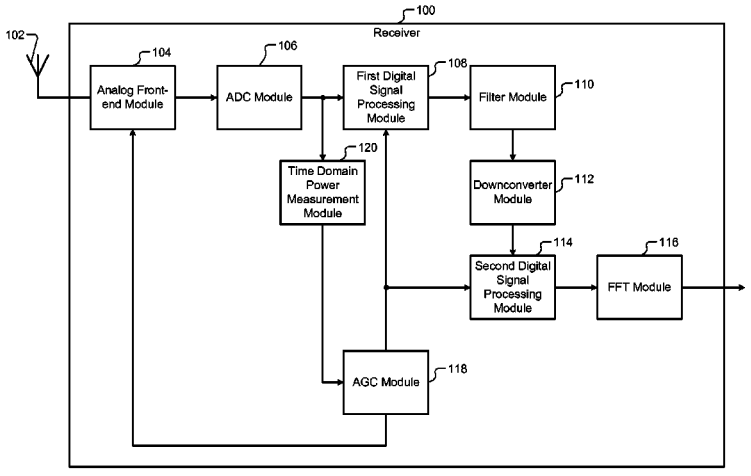
Primary Examiner — Farah Faroul

(57) **ABSTRACT**

A system including a first power measuring module, a gain control module, and a signal processing module. The first power measuring module is configured to generate a first power measurement of a signal received by a receiver of a wireless device based on a plurality of reference signals received in the signal by the receiver of the wireless device. Each of the plurality of reference signals is transmitted at a predetermined power. The first power measurement is generated in frequency domain. The first power measurement is generated during a first frame of the signal received by the receiver of the wireless device. The gain control module is configured to adjust a gain of the receiver of the wireless device based on the first power measurement. The signal processing module is configured to process a second frame in the signal subsequent to the first frame at the adjusted gain.

18 Claims, 9 Drawing Sheets



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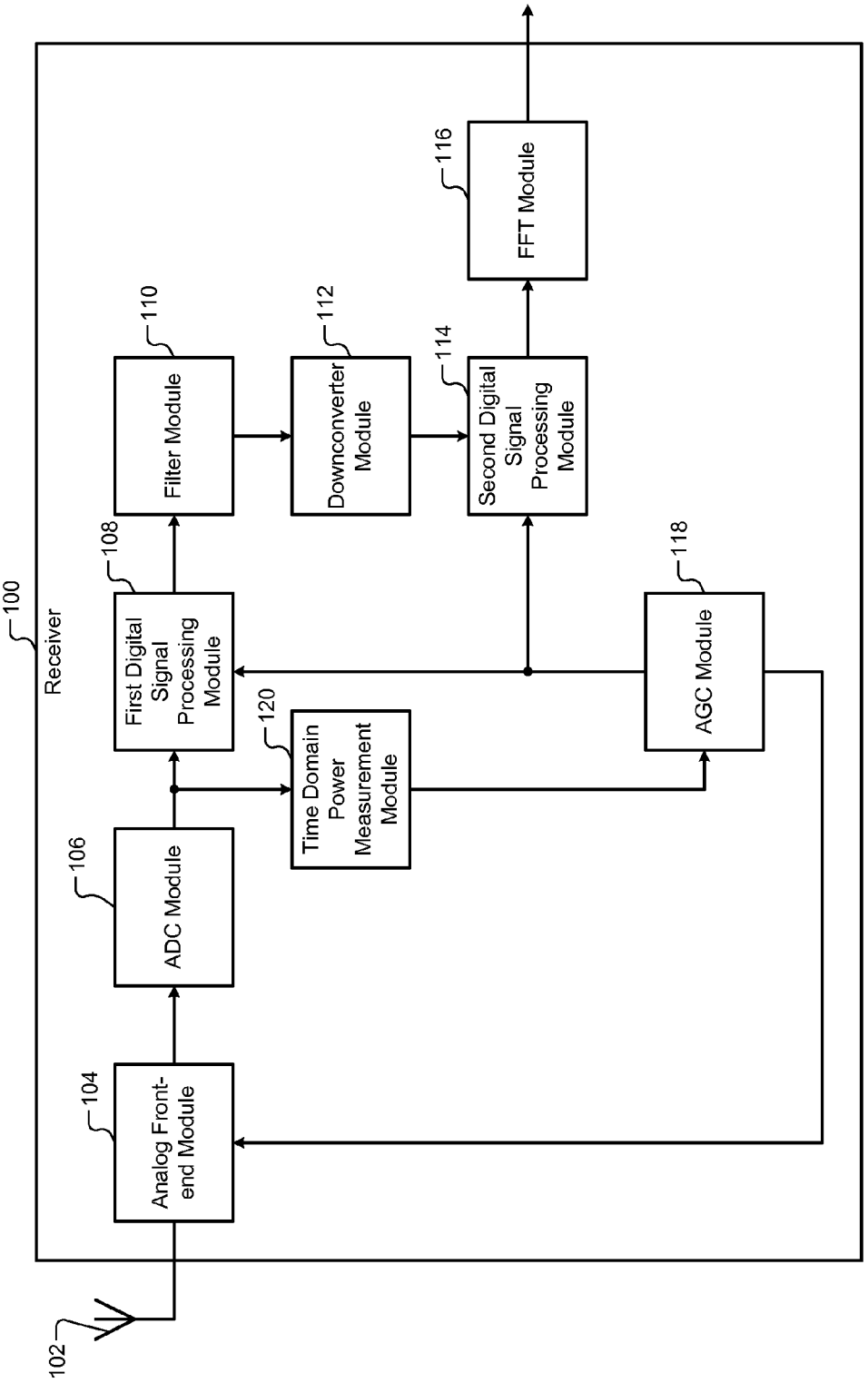
100
Receiver
102
104
Analog Front-end Module
106
ADC Module
108
First Digital Signal Processing Module
110
Filter Module
112
Downconverter Module
114
Second Digital Signal Processing Module
116
FFT Module
118
AGC Module
120
Time Domain Power Measurement Module

FIG. 1

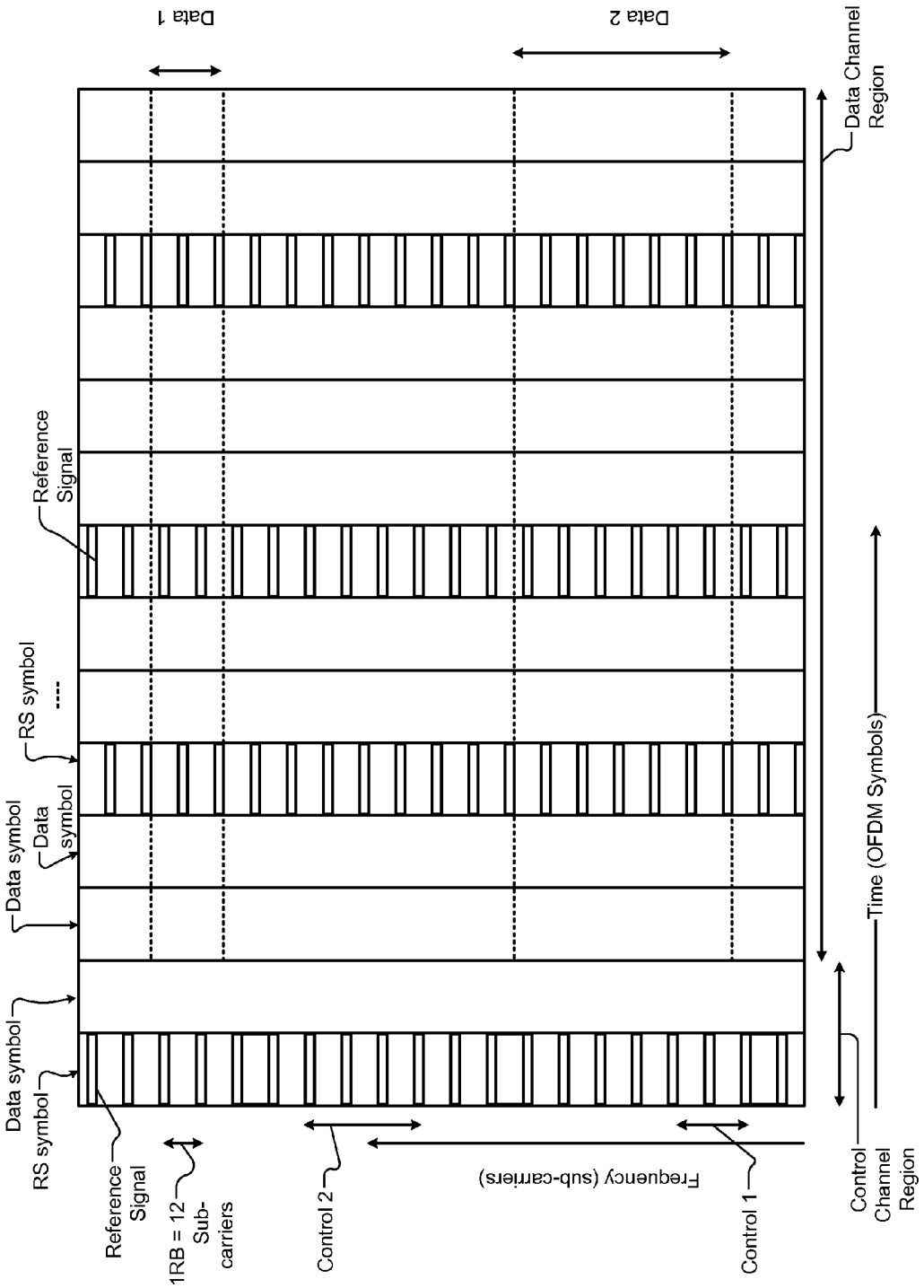
Data 1
Data 2
Data Channel Region
Reference Signal
RS symbol
Data symbol
Data symbol
Data symbol
RS symbol
Reference Signal
1RB = 12 Sub-carriers
Control 2
Frequency (sub-carriers)
Control 1
Control Channel Region
Time (OFDM Symbols)

FIG. 2

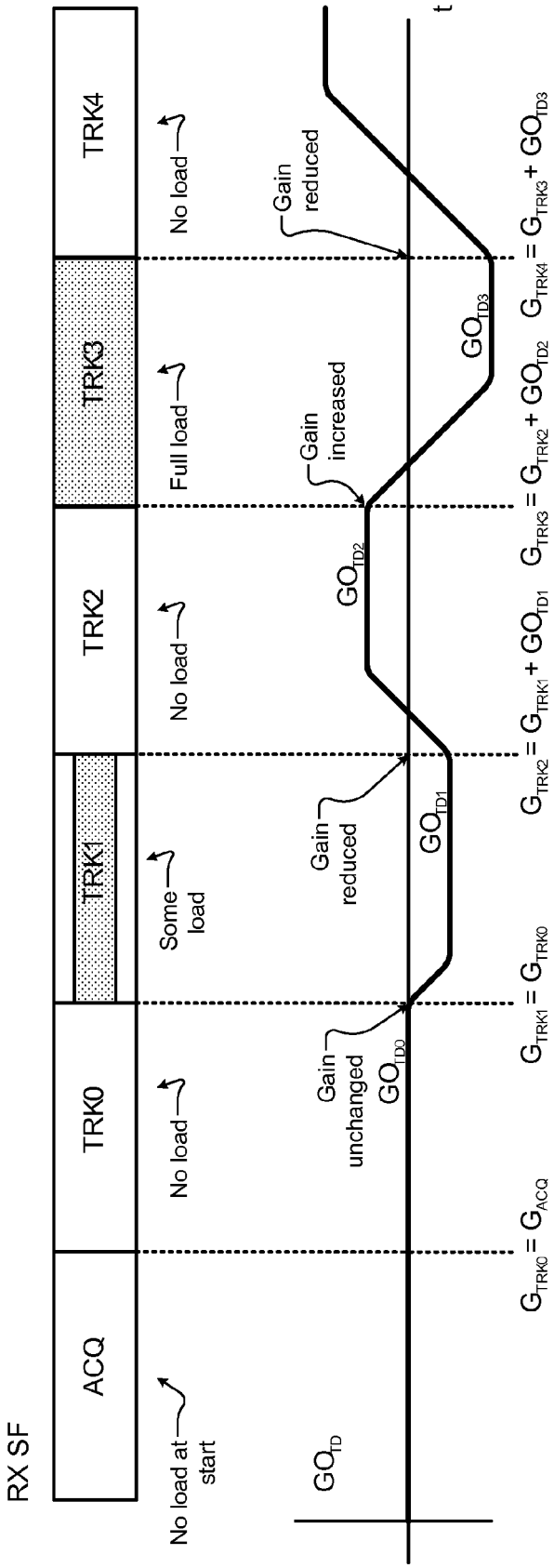
RX SF
ACQ
TRK0
TRK1
TRK2
TRK3
TRK4
No load at start
No load
Some load
No load
Full load
No load
Gain unchanged
Gain reduced
Gain increased
Gain reduced
GO_{TD}
GO_{TD0}
GO_{TD1}
GO_{TD2}
GO_{TD3}
t
$G_{TRK0} = G_{ACQ}$
$G_{TRK1} = G_{TRK0}$
$G_{TRK2} = G_{TRK1} + GO_{TD1}$
$G_{TRK3} = G_{TRK2} + GO_{TD2}$
$G_{TRK4} = G_{TRK3} + GO_{TD3}$

FIG. 3A

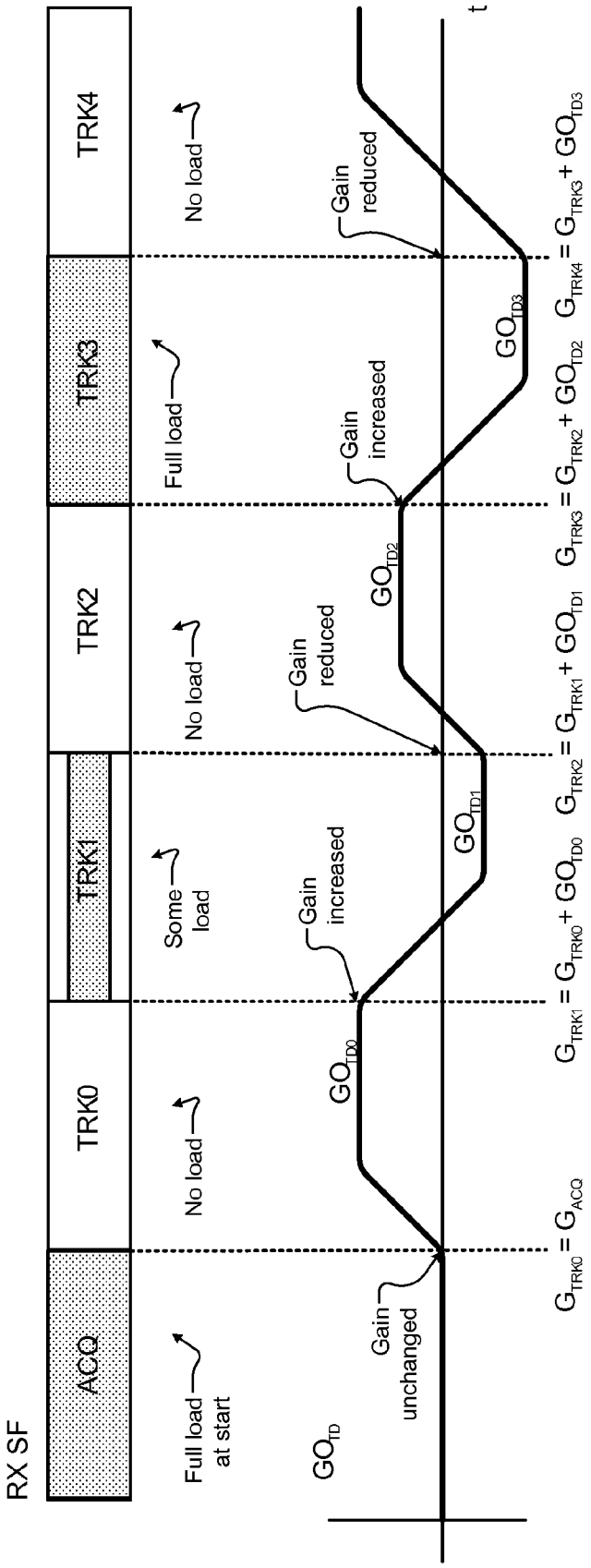
RX SF
ACQ
TRK0
TRK1
TRK2
TRK3
TRK4
Full load at start
No load
Some load
No load
Full load
No load
Gain unchanged
Gain increased
Gain reduced
Gain increased
Gain reduced
GO_{TD}
GO_{TD0}
GO_{TD1}
GO_{TD2}
GO_{TD3}
$G_{TRK0} = G_{ACQ}$
$G_{TRK1} = G_{TRK0} + GO_{TD0}$
$G_{TRK2} = G_{TRK1} + GO_{TD1}$
$G_{TRK3} = G_{TRK2} + GO_{TD2}$
$G_{TRK4} = G_{TRK3} + GO_{TD3}$
t

FIG. 3B

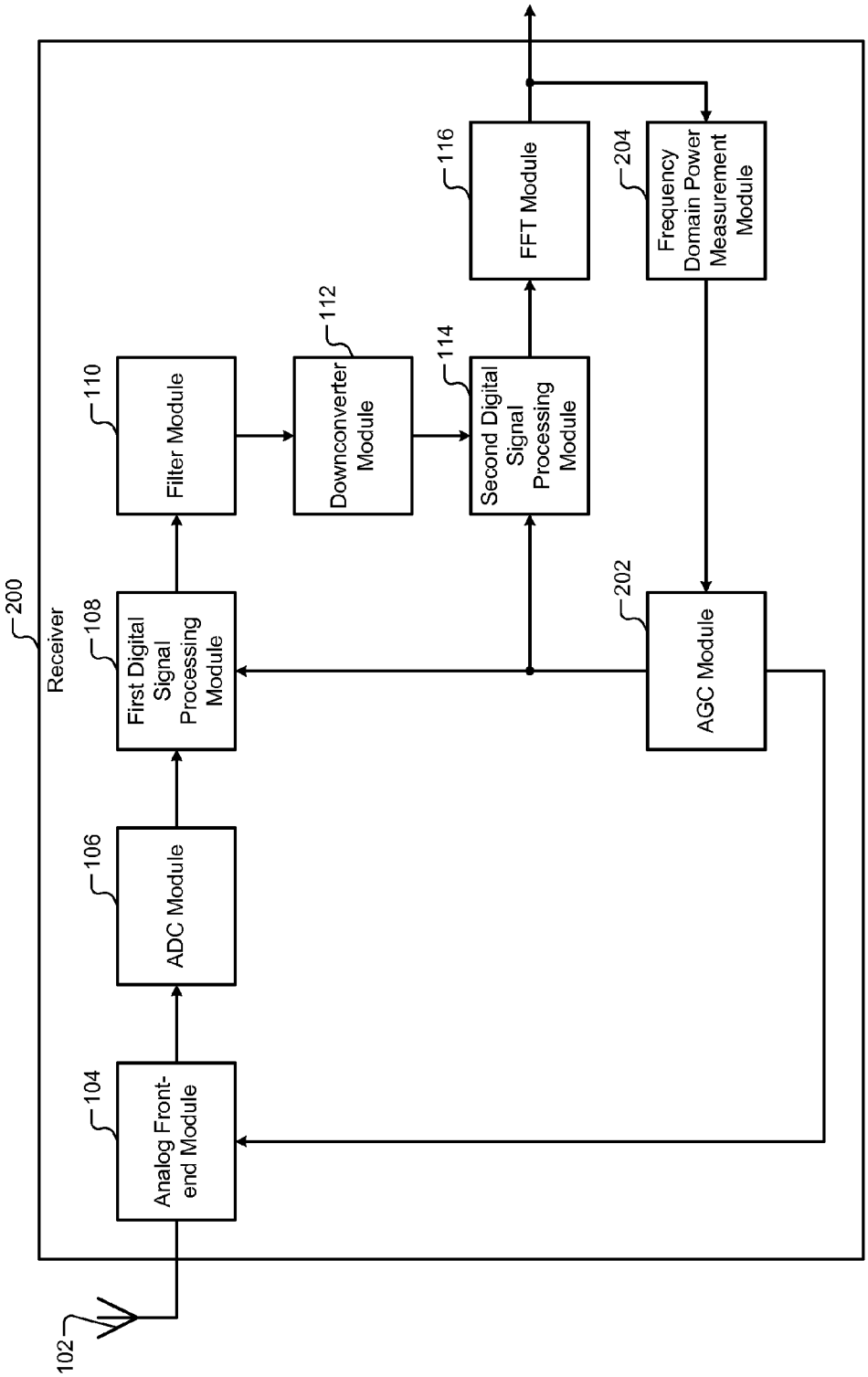
200
Receiver
102
104
Analog Front-end Module
106
ADC Module
108
First Digital Signal Processing Module
110
Filter Module
112
Downconverter Module
114
Second Digital Signal Processing Module
116
FFT Module
202
AGC Module
204
Frequency Domain Power Measurement Module

FIG. 4A

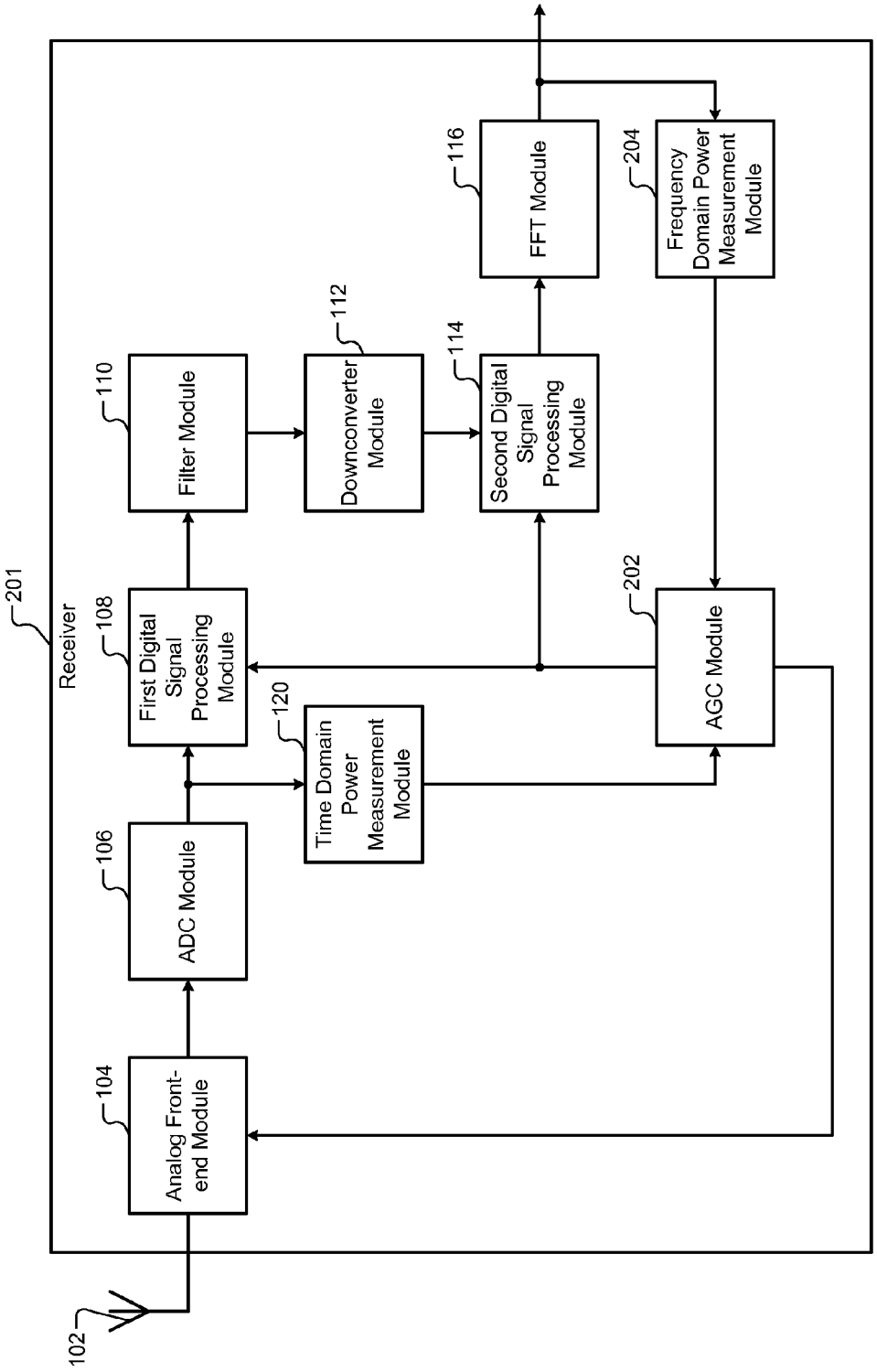
201
Receiver
102
104
Analog Front-end Module
106
ADC Module
108
First Digital Signal Processing Module
110
Filter Module
112
Downconverter Module
114
Second Digital Signal Processing Module
116
FFT Module
120
Time Domain Power Measurement Module
202
AGC Module
204
Frequency Domain Power Measurement Module

FIG. 4B

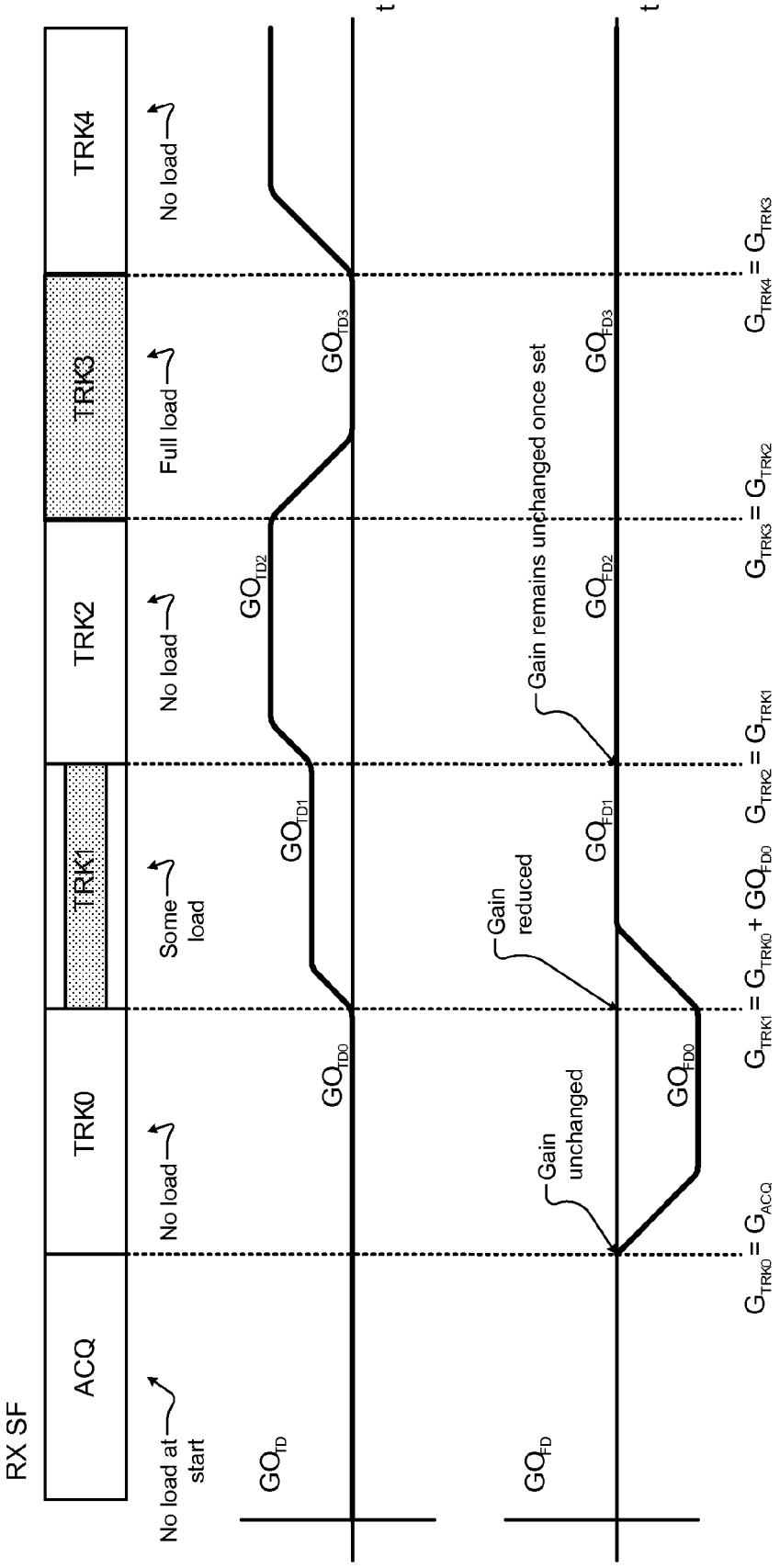
RX SF
ACQ
TRK0
TRK1
TRK2
TRK3
TRK4
No load at start
No load
Some load
No load
Full load
No load
GO_{TD}
GO_{TD0}
GO_{TD1}
GO_{TD2}
GO_{TD3}
GO_{FD}
GO_{FD0}
GO_{FD1}
GO_{FD2}
GO_{FD3}
Gain unchanged
Gain reduced
Gain remains unchanged once set
t
t
$G_{TRK0} = G_{ACQ}$
$G_{TRK1} = G_{TRK0} + GO_{FD0}$
$G_{TRK2} = G_{TRK1}$
$G_{TRK3} = G_{TRK2}$
$G_{TRK4} = G_{TRK3}$

FIG. 5A

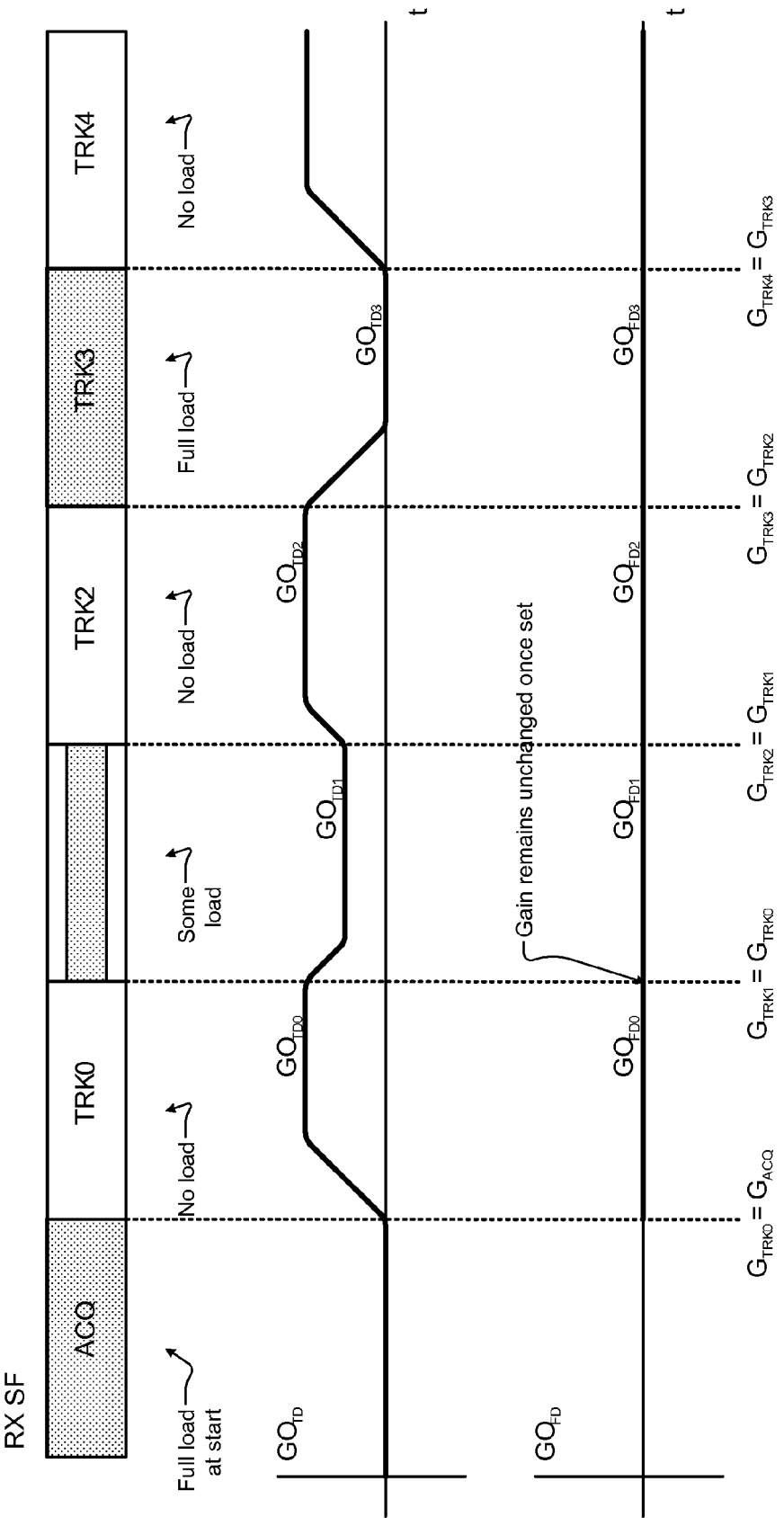
RX SF
ACQ
TRK0
TRK2
TRK3
TRK4
Full load at start
No load
Some load
No load
Full load
No load
GO_{TD0}
GO_{TD1}
GO_{TD2}
GO_{TD3}
GO_{TD}
t
Gain remains unchanged once set
GO_{FD0}
GO_{FD1}
GO_{FD2}
GO_{FD3}
GO_{FD}
t
$G_{TRK0} = G_{ACQ}$
$G_{TRK1} = G_{TRK0}$
$G_{TRK2} = G_{TRK1}$
$G_{TRK3} = G_{TRK2}$
$G_{TRK4} = G_{TRK3}$

FIG. 5B

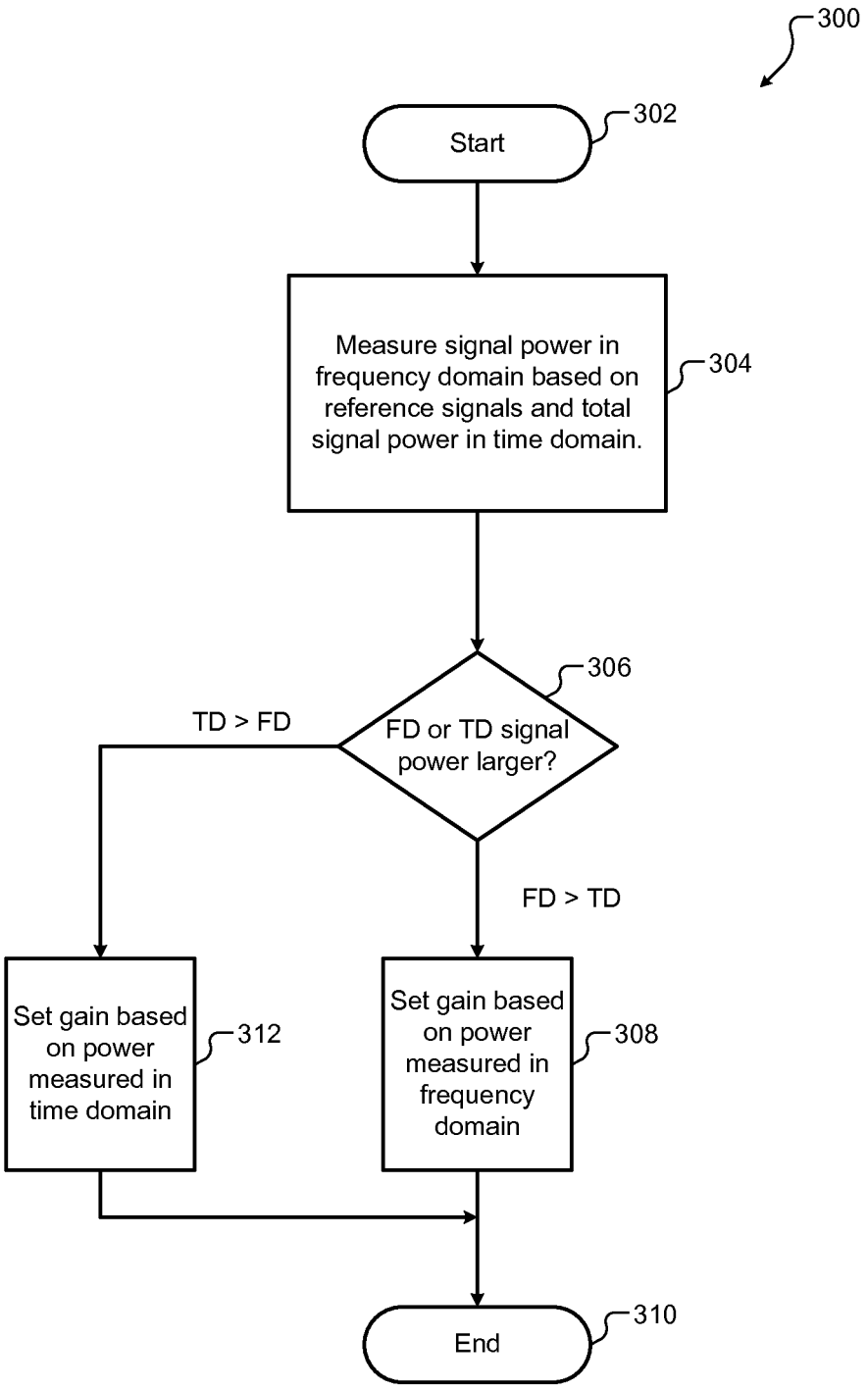
300
Start
302
Measure signal power in frequency domain based on reference signals and total signal power in time domain.
304
FD or TD signal power larger?
306
TD > FD
FD > TD
Set gain based on power measured in time domain
312
Set gain based on power measured in frequency domain
308
End
310

FIG. 6

METHOD AND APPARATUS FOR ADJUSTING A GAIN OF A RECEIVER IN A WIRELESS DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

The present disclosure is continuation of U.S. patent application Ser. No. 13/101,628 (now U.S. Pat. No. 8,773,966), filed on May 5, 2011, which claims the benefit of U.S. Provisional Application No. 61/332,601, filed on May 7, 2010. The entire disclosures of the applications referenced above are incorporated herein by reference.

FIELD

The present disclosure relates generally to communication systems and more particularly to signal power measurement and automatic gain control in orthogonal frequency division multiple access (OFDMA) systems.

BACKGROUND

The background description provided herein is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent the work is described in this background section, as well as aspects of the description that may not otherwise qualify as prior art at the time of filing, are neither expressly nor impliedly admitted as prior art against the present disclosure.

In many communication systems, transmitters encode and modulate signals before transmission, and receivers demodulate and decode received signals. Many receivers use some form of automatic gain control to adjust gain of one or more receiver components so that the received signals can be correctly demodulated and decoded.

SUMMARY

A receiver of a wireless communication device, the receiver including a fast Fourier transform module, a first power measuring module, and a gain control module. The fast Fourier transform module is configured to convert a signal from a time domain to a frequency domain. The signal includes a plurality of reference signals. The reference signals have a predetermined power. The first power measuring module is configured to generate a first power measurement of the signal in the frequency domain based on the plurality of reference signals. The gain control module is configured to adjust a gain of the receiver based on the first power measurement.

A method for a receiver of a wireless communication device, the method including converting a signal received by the receiver from a time domain to a frequency domain. The signal includes a plurality of reference signals. The reference signals have a predetermined power. The method further includes generating a first power measurement of the signal in the frequency domain based on the plurality of reference signals and adjusting a gain of the receiver based on the first power measurement.

Further areas of applicability of the present disclosure will become apparent from the detailed description, the claims and the drawings. The detailed description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the disclosure.

BRIEF DESCRIPTION OF DRAWINGS

The present disclosure will become more fully understood from the detailed description and the accompanying drawings, wherein:

FIG. **1** is a functional block diagram of a receiver of a wireless communication device, where the receiver sets a gain of one or more receiver components based on signal power measured in the time domain;

FIG. **2** depicts an example of a long term evolution (LTE) sub-frame;

FIGS. **3**A and **3**B depict examples of gain variation in a receiver when the gain of the receiver components is set based on signal power measured in the time domain;

FIG. **4**A is a functional block diagram of a receiver that sets the gain of the receiver components based on signal power measured in the frequency domain;

FIG. **4**B is a functional block diagram of a receiver that sets the gain of the receiver components based on signal power measured in at least one of the time domain and the frequency domain;

FIGS. **5**A and **5**B depict examples of gain variation in a receiver when the gain of the receiver components is set based on signal power measured in the frequency domain; and

FIG. **6** is a flowchart of a method for setting the gain of the receiver components based on signal power measured in at least one of the time domain and the frequency domain.

DESCRIPTION

The following description is merely illustrative in nature and is in no way intended to limit the disclosure, its application, or uses. For purposes of clarity, the same reference numbers will be used in the drawings to identify similar elements. As used herein, the phrase at least one of A, B, and C should be construed to mean a logical (A or B or C), using a non-exclusive logical OR. It should be understood that steps within a method may be executed in different order without altering the principles of the present disclosure.

As used herein, the term module may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC); an electronic circuit; a combinational logic circuit; a field programmable gate array (FPGA); a processor (shared, dedicated, or group) that executes code; other suitable components that provide the described functionality; or a combination of some or all of the above, such as in a system-on-chip. The term module may include memory (shared, dedicated, or group) that stores code executed by the processor.

The term code, as used above, may include software, firmware, and/or microcode, and may refer to programs, routines, functions, classes, and/or objects. The term shared, as used above, means that some or all code from multiple modules may be executed using a single (shared) processor. In addition, some or all code from multiple modules may be stored by a single (shared) memory. The term group, as used above, means that some or all code from a single module may be executed using a group of processors. In addition, some or all code from a single module may be stored using a group of memories.

The apparatuses and methods described herein may be implemented by one or more computer programs executed by one or more processors. The computer programs include processor-executable instructions that are stored on a non-transitory tangible computer readable medium. The computer programs may also include stored data. Non-limiting

examples of the non-transitory tangible computer readable medium are nonvolatile memory, magnetic storage, and optical storage.

The present disclosure relates to an automatic gain control in a receiver of a wireless device, where the receiver sets the gain of receiver components based on signal power measured in the frequency domain. Specifically, the automatic gain control measures the signal power in frequency domain based on reference signals (pilots) included in a received sub-frame. At the end of the sub-frame, the automatic gain control adjusts the gain of the receiver components according to the measured signal power. The receiver processes the subsequent sub-frame according to the adjusted gain. While the automatic gain control measures the signal power in frequency domain during a sub-frame, the automatic gain control adjusts the gain of the receiver components according to the measured signal power at a sub-frame boundary that follows.

Referring now to FIG. **1**, a receiver **100** of a wireless communication device is shown. The receiver **100** uses AGC to set gain of the receiver components according to signal power measured in the time domain. The receiver **100** includes an antenna **102**, an analog front-end (AFE) module **104**, an analog-to-digital converter (ADC) module **106**, a first digital signal processing (DSP) module **108**, a filter module **110**, a downconverter module **112**, a second DSP module **114**, a fast Fourier transform (FFT) module **116**, an automatic gain control (AGC) module **118**, and the time domain (TD) power measurement module **120**. The receiver **100** receives signals via the antenna **102**. Although one antenna is shown, the receiver **100** may include a plurality of antennas. For example, the plurality of antennas may be arranged in a multiple-input multiple-output (MIMO) configuration.

The AFE module **104** processes the signals received via the antenna **102**. For example, the AFE module **104** may demodulate the signals received via the antenna **102**. The ADC module **106** converts an output of the AFE module **104** from analog to digital format. The first DSP module **108** processes an output of the ADC module **106**. The filter module **110** filters an output of the first DSP module **108**. For example, the filter module **110** may include a low-pass filter module.

The downconverter module **112** downconverts an output of the filter module **110**. The second DSP module **114** processes an output of the downconverter module **112**. The FFT module **116** converts an output of the second DSP module **114** from the time domain to frequency domain. An output of the FFT module **116** is further processed by other modules (not shown) of the receiver **100** in frequency domain. For example, a channel estimation module (not shown) of the receiver **100** may generate a channel estimate based on the output of the FFT module **116**.

The AGC module **118** controls the gain of the AFE module **104**, the first DSP module **108**, and the second DSP module **114**. The TD power measurement module **120** measures the signal power of the received signals in the time domain and outputs the signal power measurement to the AGC module **118**. The AGC module **118** adjusts the gain of the AFE module **104**, the first DSP module **108**, and the second DSP module **114** based on the signal power measurement in the time domain.

In systems such as Worldwide Interoperability for Microwave Access (WiMAX) systems using orthogonal frequency division multiplexing (OFDM), data are transmitted in frames. Each frame includes a plurality of OFDM symbols. A first OFDM symbol of a frame includes a preamble. When a receiver receives a frame, the signal power of the frame is measured within a cyclic prefix (CP) of the preamble present in the first OFDM symbol of the frame. The gain of the receiver components is set according to the signal power measured based on the preamble in the time domain.

The preamble facilitates signal power measurements due to the following properties of the preamble. The signal power of the preamble is unchanged across the frames. Further, since no data other than the preamble is carried in the first OFDM symbol, the signal power measured based on the preamble does not depend on resource allocation, which can cause variation in signal power measured based on data symbols in the frames. Further, the preamble is a wideband signal with a time-domain signal power variation contained within a ±3 dB range in the CP. Accordingly, any errors in setting the gain and decoding data in the frames are limited to ±3 dB.

Frames of many OFDMA systems such as Long Term Evolution (LTE) systems specified by 3rd Generation Partnership Project (3GPP), however, may not include signals like the preamble in the WiMAX systems. Accordingly, in these systems, the signal power measurements may have to be based on symbols that carry user data. Measuring signal power based on user data presents the following problems.

Depending on the amount of user data carried in the frames, narrow band allocations are likely to occur. Measuring narrow band signal power in a small measurement window (e.g., within CP), however, can cause large errors in signal power measurements. Hence, the signal power must be measured in a larger window (e.g., within a sub-frame or several sub-frames). Additionally, based on the amount of user data, resource allocation across the frames may vary dynamically. Dynamic resource allocation may result in OFDM symbols with varying time-domain symbol powers across the frames. Accordingly, a gain setting derived from signal power measured based on data in one frame may not be suitable for processing a subsequent frame.

Referring now to FIG. **2**, an example of an LTE sub-frame is shown. Data are located in the LTE sub-frame in increments of one resource block (RB). A resource block includes a predetermined number of sub-carriers (e.g., 1 RB=12 sub-carriers). The LTE sub-frame does not include preamble. Instead, the LTE sub-frame includes reference signals, which are also called pilot signals or pilots. In the example shown, the LTE sub-frame includes two reference signals per resource block (i.e., one reference signal (RS) for every six sub-carriers). The number of reference signals per resource block is proportional to the number of antennas in the receiver.

In the LTE sub-frame, symbols carrying the reference signals and user data are called RS symbols, and symbols carrying user data and no reference signals are called data symbols. An RS symbol includes both reference signals and user data, each occupying different sub-carriers (frequencies). Each LTE sub-frame can include a plurality of RS symbols and a plurality data symbols as shown. In an RS symbol, a ratio of a number of RS sub-carriers (i.e., a number of sub-carriers used to carry the reference signals) in a resource block to a total number of sub-carriers in the resource block is called a reference signal density.

The LTE sub-frame includes a control channel region and a data channel region. A first plurality of symbols in the LTE sub-frame is in the control channel region. A second plurality of symbols in the LTE sub-frame is in the data channel region. In the example shown, two control channels (control 1 and control 2) and two data channels (data 1 and data 2) are allocated in the LTE sub-frame. The control channel 1 (control 1) controls resource allocation of the data channel 1 (data 1), and the control channel 2 (control 2) controls resource

allocation of the data channel 2 (data 2). In general, one or more control channels and one or more data channels may be used. Signal power in the control channel region is not representative of the signal power in the data channel region.

Narrow band allocation in OFDMA systems causes large variation in time domain signal power estimates. Specifically, since signal power varies within a symbol, the signal power measurement may differ depending on a size of a measurement window used to measure the signal power. For example, the signal power measured using a measurement window of size CP/4 can be different than the signal power measured using a measurement window of size CP/2 or 3CP/4.

In other words, signal power estimation is a function of a window length and signal properties. A small measurement window tends to yield an instantaneous signal power estimate instead of an average signal power estimate. Accordingly, errors in signal power measurement can be pronounced when small measurement windows are used to measure signal power. Data can be lost if gain is set according to erroneous signal power measurements.

Further, even if the number of gain updates is limited to one, and a full CP is used for signal power measurement to reduce the error, the variation in the signal power measurement precludes the AGC module from updating the gain within a CP based on the signal power measured in the current symbol. In other words, without the preamble, signal power cannot be measured reliably based on the first symbol of a sub-frame, and gain to process the sub-frame cannot be set correctly based on the signal power measured during the first symbol of the sub-frame. Specifically, in the time domain, by the time signal power is measured based on the first symbol, the first symbol is lost. Accordingly, signal power must be measured in a previous sub-frame, and gain to process a subsequent sub-frame must be set based on the signal power measured in the previous sub-frame.

Signal power measured in a previous sub-frame, however, cannot be used to set the gain to process a subsequent frame because resource allocation may differ from one frame to another. Consequently, the signal power may also differ from one frame to another. As a result, a gain setting derived from the signal power measured in a previous sub-frame cannot be used to process a subsequent sub-frame.

For example, an empty sub-frame allocation results in empty OFDM symbols, which yield very small power estimates that should be excluded when setting the gain. This, together with the fact that the gain to process a current sub-frame is set based on the signal power measured in a previous sub-frame, precludes symbol by symbol gain adjustment in AGC tracking.

Accordingly, the time domain power measurements should be aggregated over a longer measurement window (e.g., over one or more sub-frames in LTE systems). Combining power measurements of symbols in one or more sub-frames in AGC tracking, however, circumvents power fluctuation from symbol to symbol but does not address power fluctuation from sub-frame to sub-frame due to difference in loading (e.g., empty sub-frame followed by fully loaded sub-frame).

Referring now to FIGS. **3**A and **3**B, examples of gain variation when gain is set based on a time domain power measurement from a preceding sub-frame are shown. The examples shown are for gain variation in an AWGN channel (i.e., a channel with no channel gain change) in order to isolate signal power changes due to changes in resource allocation from the changes in channel gains. In the examples, a gain offset (GO) indicates a gain error in a sub-frame.

In FIG. **3**A, the AGC module begins gain control with an initial gain setting, and a first sub-frame received is empty (i.e., no load). The AGC module measures signal power in a previous sub-frame and sets the gain to process the following sub-frame based on the signal power measured in the previous sub-frame as shown. Note that the gain variation is worse when an empty sub-frame is followed by a fully loaded sub-frame.

In FIG. **3**B, the AGC module begins with an initial gain setting, and a first subframe received is full (i.e., full load). The AGC module measures signal power in a previous sub-frame and sets the gain to process the following sub-frame based on the signal power measured in the previous sub-frame as shown. As FIGS. **3**A and **3**B indicate, different loading of the sub-frames causes large gain variation, and time-domain power measurements alone are insufficient for proper AGC tracking.

The present disclosure relates to measuring signal power based on reference signals (pilots) included in a sub-frame and setting the gain of the receiver components that process the sub-frame based on the signal power measured based on the reference signals in frequency domain. Each sub-frame includes the reference signals at predetermined locations (called resource elements) in time and frequency as shown in FIG. **2**. Note that the reference signals are different than a preamble, a cyclic prefix, a guard band, a sub-carrier, a training signal, and user data. Rather, to facilitate channel estimation at the receiver, the reference signals are specifically transmitted with a predetermined signal power that is independent of resource allocation in the sub-frame. Further, the resource signals cover the full bandwidth and are therefore particularly suitable for accurately estimating signal power at the receiver.

Additionally, no extra processing is required at the receiver to extract the reference signals for measuring signal power since the reference signals are automatically extracted by the FFT module of the receiver for channel estimation. Accordingly, the reference signals are readily available for measuring signal power in the frequency domain. The present disclosure relates to measuring the signal power in the frequency domain based on the reference signals and setting the gain of the receiver components based on the frequency domain signal power measurement. The time domain signal power measurement is combined with the frequency domain signal power measurement to set the gain of the receiver components. Both time and frequency domain signal power measurements are used since most wireless receivers operate in presence of blockers (e.g., narrow band blockers, adjacent and non-adjacent channel blockers, etc.), and most RF receivers do not completely filter out signals outside of the channel of interest.

Referring now to FIG. **4**A, a receiver **200** of a wireless communication device is shown. The receiver **200** uses AGC to set gain of the receiver components according to signal power measured in the frequency domain. The receiver **200** includes the antenna **102**, the analog front-end (AFE) module **104**, the analog-to-digital converter (ADC) module **106**, the first digital signal processing (DSP) module **108**, the filter module **110**, the downconverter module **112**, the second DSP module **114**, the fast Fourier transform (FFT) module **116**, an automatic gain control (AGC) module **202**, and a frequency domain (FD) power measurement module **204**.

The AGC module **202** controls the gain of the AFE module **104**, the first DSP module **108**, and the second DSP module **114** (collectively referred to as the receiver components). The FD power measurement module **204** measures the signal power of the received signals in frequency domain as explained below and outputs the signal power measurement to the AGC module **202**. The AGC module **202** adjusts the

gain of the receiver components based on the signal power measurement in frequency domain.

Mathematically, a relationship between time-domain root mean square (RMS) of a received signal and frequency-domain RMS of the received signal can be expressed by the following equation (assuming full loading with equal sub-carrier powers):

$$RMS_{TD_i}^2 = \frac{1}{N}\sum_{n=0}^{N-1}|y_i(n)|^2 = \frac{1}{N^2}\sum_{k\in\Omega_{sc}}|Y_i(k)|^2 = \frac{1}{\rho_{RS}\cdot N^2}\sum_{k\in\Omega_{RS}}|Y_i(k)|^2$$

In the equation, $y_i(n)$ denotes the received signal in the time domain, and $Y_i(k)$ denotes the received signal in frequency domain. ρ_{RS} denotes a reference signal density (i.e., a ratio of number of RS sub-carriers in a resource block to a total number of sub-carriers in the resource block as defined earlier). For example, in FIG. **2**, ρ_{RS}=1/6 since two reference signals are used per resource block of 12 sub-carriers (i.e., 1 reference signal is used every six sub-carriers). N denotes FFT size (e.g., N=512, 1024, etc.). Ω_{sc} denotes a set of sub-carriers used (which may differ from the FFT size), and Ω_{RS} denotes a set of reference signal sub-carriers. i denotes a receive antenna index (e.g., i can be 0 or 1 for two receive antennas). Note that the signal power equals RMS_2 divided by a termination impedance.

The FD power measurement module **204** measures the frequency-domain RMS of RS sub-carriers for each receive antenna i over RS sub-carriers in each RS symbol m. The FD power measurement module **204** can perform the measurement within a predetermined measurement interval. For example, the predetermined measurement interval can be one or more LTE sub-frames. The FD power measurement module **204** measures the frequency-domain RMS of RS sub-carriers for each receive antenna i over RS sub-carriers in each RS symbol m within the predetermined measurement interval based on the following equation:

$$RMS_{RS}^2(i,m) = \frac{1}{N^2}\sum_{k\in\Omega_{RS}}|Y_{i,m}(k)|^2$$

Note that the FD power measurement module **204** measures the frequency-domain RMS of RS sub-carriers only based on RS symbols and not based on data symbols (shown in FIG. **2**).

The FD power measurement module **204** averages the frequency-domain RMS of RS sub-carriers measured as above over all N_{RS} RS symbols in the predetermined measurement interval using the following equation:

$$RMS_{RS}^2 = \max_i \frac{1}{N_{RS}}\sum_{m=0}^{N_{RS}-1} RMS_{RS}^2(i,m)$$

In some systems, a single AGC may control the gain of the receiver components that process signals received via multiple antennas. In such systems, the FD power measurement module **204** finds a maximum of the averaged signal powers measured for the i antennas as indicated above. The FD power measurement module **204** uses the maximum to set the gain of the receiver components.

In systems where a separate AGC is used to set the gain of the receiver components that process signals received via each antenna, the maximum is not used. Instead, the averaged signal power for each antenna calculated as above is used to set the gain of the receiver components associated with the respective antenna.

The AGC module **202** generates a frequency domain gain offset (GO_{FD}), which is an amount by which the AGC module **202** adjusts the gain of the receiver components, using the following equation:

$$GO_{FD}=10\log_{10}(RMS_{RS_{target}}^2/RMS_{RS}^S)$$

$$RS_{RS_{target}}^2=\rho_{RS}\cdot RMS_{TD_{target}}^2$$

In the equation, values that are subscripted with the word "target" indicate respective desired values. The AGC module **202** can also determine the gain offset GO_{FD} using a lookup table.

Setting the gain based on the signal power measured in the time domain ensures a constant total signal power. In contrast, setting the gain based on the signal power measured in frequency domain ensures a constant power spectral density (i.e., constant signal power in frequency domain) regardless of resource allocation. For example, the signal power measured in frequency domain is unchanged regardless of the whether one resource block or 100 resource blocks are allocated in an LTE sub-frame. Accordingly, the output of the FFT module **116** is unchanged even when the output of the time-domain power measurement module **120** changes due to changes in resource allocation.

Referring now to FIG. **4**B, a receiver **201** of a wireless communication device is shown. The receiver **201** uses AGC to set gain of the receiver components according to signal power measured in frequency domain and the time domain. The receiver **201** includes all the modules of the receiver **200** and additionally includes the time-domain power measurement module **120**. Frequency-domain power measurement described above accurately measures power within a desired channel bandwidth and is sufficient if signals outside of desired channel bandwidth (i.e., blockers) are not present. Further, the frequency domain power measurement works equally well on both AWGN and fading channels in the absence of blockers. Blockers from adjacent channels, however, can adversely impact the output of the ADC module **106** if the blockers are not filtered out effectively. Accordingly, the time-domain power measurement should be combined with the frequency-domain power measurement to set the gain of the receiver components.

Specifically, the AGC module **202** should select a minimum of the frequency domain gain offset and the time domain gain offset GO_{TD} and should use the minimum to set the gain of the receiver components. The AGC module **202** determines the time-domain gain offset GO_{TD} based on the total signal power in the time domain measured by the time-domain power measurement module **118** and a desired signal power. Combining time and frequency domain power gain offsets is mathematically expressed by the following equation:

$$GO=\min(GO_{TD},GO_{FD})$$

Accordingly, the AGC module **202** will set the gain of the receiver components based on a greater of the frequency-domain power measurement and the time-domain power measurement to minimize the effect of blockers on the output of the ADC module **106**.

Referring now to FIGS. **5**A and **5**B, examples of gain variation when gain is set based on a frequency-domain

power measurement from a preceding sub-frame are shown. The examples shown are for gain variation in absence of residual blocker power in an additive white Gaussian noise (AWGN) channel (i.e., a channel with no channel gain change) in order to isolate signal power changes due to changes in resource allocation from the changes in channel gains. In FIG. **5**A, the AGC module **202** begins with an initial gain setting, and a first sub-frame received is empty (i.e., no load). The AGC module **202** measures signal power in a previous sub-frame in frequency domain based on the reference signals in the sub-frame. Note that the reference signal RMS target defined earlier is selected such that, in absence of residual blocker power, frequency domain gain offset is always equal to the time domain gain offset for fully allocated sub-frame regardless of the actual allocation. Thus, although the first sub-frame received is empty, the AGC module **202** will decrease the gain to a level necessary to process a fully allocated sub-frame as shown.

After the gain is set, assuming blockers are filtered, the AGC module **202** does not need to change the gain to process subsequent sub-frames. This is because the AGC module **202** sets the gain according to signal power measured based on the reference signals independently of resource allocation of the sub-frame in which the signal power is measured. Note that the time-domain gain offset varies but is disregarded when setting the gain (assuming blockers are filtered).

In FIG. **5**B, the AGC module **202** begins with an initial gain setting, and a first sub-frame received is full (i.e., full load). The AGC module **202** measures signal power in a previous sub-frame in the frequency domain based on the reference signals in the sub-frame and sets the gain to process the following frame based on the signal power measured in the previous frame as shown. As FIGS. **5**A and **5**B indicate, different loading of the sub-frames does not causes large gain variation, and the frequency-domain power measurement is sufficient for AGC tracking when blockers are filtered.

In summary, setting the gain of the receiver components by measuring signal power in the frequency domain based on the reference signals eliminates gain fluctuation (errors) due to dynamic resource allocation. This can reduce bit width of receiver data path modules by at least two bits. For example, in LTE systems where gain can vary between 8 dB and 13 dB, precision (i.e., dynamic range) of the ADC module **106** and precision of other time-domain and frequency-domain data processing circuits can be reduced by at least 2 bits, which would be otherwise necessary to provide headroom for gain variation between 8 dB and 13 dB. Further, using time-domain and frequency domain power measurements to set gain prevents the output of the ADC module **106** from saturating in case of residual blocker leakage.

Referring now to FIG. **6**, a method **300** for setting gain of receiver components of a wireless communication device is shown. Control begins at **302**. At **304**, control measures signal power in frequency domain based on reference signals in the received signal and the total signal power in the time domain. At **306**, control determines if the time or frequency domain signal power is larger. At **308**, if the frequency domain signal power is larger, control sets the gain of the receiver components based on the signal power measured in frequency domain based on the reference signals, and control ends at **310**. At **312**, if the time domain signal power is larger, controls sets the gain of the receiver components based on the signal power measured in the time domain, and control ends at **310**.

The teachings of the present disclosure are applicable to all OFDMA systems (e.g., WiMAX, LTE, etc.) since the power measurement and gain setting disclosed herein relies only on reference signals. The teachings can be further extended to other systems that use dynamic resource allocation and that include signals similar to the pilots.

The broad teachings of the disclosure can be implemented in a variety of forms. Therefore, while this disclosure includes particular examples, the true scope of the disclosure should not be so limited since other modifications will become apparent upon a study of the drawings, the specification, and the following claims.

What is claimed is:

1. A system comprising:

a first power measuring module configured to

generate a first power measurement of a signal received by a receiver of a wireless device, the first power measurement of the signal being generated based on a plurality of reference signals associated with the signal received by the receiver of the wireless device,

wherein each of the plurality of reference signals is transmitted at a predetermined power,

wherein the first power measurement is generated in frequency domain, and

wherein the first power measurement is generated during a first frame of the signal received by the receiver of the wireless device;

a second power measuring module configured to generate a second power measurement of the signal in time domain;

a gain control module configured to adjust a gain of the receiver based on (i) the first power measurement and (ii) the second power measurement; and

a signal processing module configured to process a second frame in the signal, wherein the second frame is subsequent to the first frame, and wherein the signal processing module processes the second frame at the gain as adjusted by the gain control module.

2. The system of claim **1**, wherein the second power measurement depends on resource allocation used in the signal.

3. The system of claim **1**, wherein the signal processing module is configured to process the second frame independently of resource allocation of frames subsequent to the first frame in the signal.

4. The system of claim **1**, further comprising:

a second power measuring module configured to generate a second power measurement of the signal in time domain,

wherein the second power measurement depends on resource allocation used in the signal, and

wherein the gain control module is configured to adjust the gain of the receiver based on the first power measurement independently of variation in the second power measurement.

5. The system of claim **1**, wherein:

the signal includes a plurality of reference symbols and a plurality of data symbols;

the first power measuring module is configured to

measure a mean square power of a set of the reference signals in each of the reference symbols within a measurement interval,

generate the first power measurement by averaging the mean square powers of the reference symbols, and

generate an offset based on the first power measurement and a desired power; and

the gain control module is configured to adjust the gain of the receiver based on the offset.

6. The system of claim **1**, the receiver comprising:

a second power measuring module configured to generate a second power measurement of the signal in time domain,

wherein the second power measurement depends on resource allocation used in the signal, and

wherein the gain control module is configured to

generate a first offset based on the first power measurement and a desired power,

generate a second offset based on the second power measurement and the desired power, and

adjust the gain of the receiver based on a smaller of (i) the first offset and (ii) the second offset.

7. The system of claim **1**, wherein:

the reference signals are present in the signal at predetermined locations; and

the reference signals do not correspond to a preamble, a cyclic prefix, a guard band, a sub-carrier, a training signal, and user data.

8. The system of claim **1**, wherein:

the signal includes sub-carriers modulated using orthogonal frequency division multiplexing; and

the reference signals are pilot signals transmitted using a predetermined number of the sub-carriers.

9. The system of claim **1**, wherein the receiver is configured to generate a channel estimate based on the reference signals.

10. A method comprising:

generating a first power measurement of a signal received by a receiver of a wireless device, the first power measurement being generated based on a plurality of reference signals received associated with the signal received by the receiver of the wireless device,

wherein each of the plurality of reference signals is transmitted at a predetermined power,

wherein the first power measurement is generated in frequency domain, and

wherein the first power measurement is generated during a first frame of the signal received by the receiver of the wireless device;

generating a second power measurement of the signal in time domain;

adjusting a gain of the receiver based on (i) the first power measurement and (ii) the second power measurement; and

processing a second frame in the signal at the adjusted gain, wherein the second frame in the signal is subsequent to the first frame in the signal.

11. The method of claim **10**, wherein the second power measurement depends on resource allocation used in the signal.

12. The method of claim **10**, further comprising the processing of the second frame independently of resource allocation of frames subsequent to the first frame in the signal.

13. The method of claim **10**, further comprising:

generating a second power measurement of the signal in time domain, wherein the second power measurement depends on resource allocation used in the signal; and

adjusting the gain of the receiver based on the first power measurement independently of variation in the second power measurement.

14. The method of claim **10**, wherein the signal includes a plurality of reference symbols and a plurality of data symbols, the method further comprising:

measuring a mean square power of a set of the reference signals in each of the reference symbols within a measurement interval,

generating the first power measurement by averaging the mean square powers of the reference symbols, and

generating an offset based on the first power measurement and a desired power; and

adjusting the gain of the receiver based on the offset.

15. The method of claim **10**, the receiver comprising:

generating a second power measurement of the signal in time domain, wherein the second power measurement depends on resource allocation used in the signal;

generating a first offset based on the first power measurement and a desired power;

generating a second offset based on the second power measurement and the desired power; and

adjusting the gain of the receiver based on a smaller of (i) the first offset and (ii) the second offset.

16. The method of claim **10**, wherein:

the reference signals are present in the signal at predetermined locations; and

the reference signals do not correspond to a preamble, a cyclic prefix, a guard band, a sub-carrier, a training signal, and user data.

17. The method of claim **10**, wherein:

the signal includes sub-carriers modulated using orthogonal frequency division multiplexing; and

the reference signals are pilot signals transmitted using a predetermined number of the sub-carriers.

18. The method of claim **10**, further comprising generating a channel estimate based on the reference signals.

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